USE OF GROUP-SELECTION AND SEED-TREE CUTS BY THREE EARLY-SUCCESSIONAL MIGRATORY SPECIES IN ARKANSAS

LYNN E. ALTERMAN,[1,3,4] JAMES C. BEDNARZ,[1] AND RONALD E. THILL[2]

ABSTRACT.—Silviculture in the Ouachita National Forest in Arkansas and Oklahoma has shifted in recent years from mostly even-aged management to a mix of even- and uneven-aged regeneration systems, including group-selection. Researchers have described presence/absence of early-successional bird species in forest openings created by even- and uneven-aged silviculture, but few have examined nest success. We examined occupancy and nest success of three early-successional species—Indigo Bunting (*Passerina cyanea*), Yellow-breasted Chat (*Icteria virens*), and Prairie Warbler (*Dendroica discolor*)—within 6- and 7-year-old openings created by group-selection (uneven-aged, ≤0.8 ha) and seed-tree (even-aged, 11–16 ha) cuts in Arkansas. We found 54 Indigo Bunting nests in openings created by seed-tree cuts and 28 in openings created by group-selection cuts (hereafter "seed-tree stands" and "group-selection stands," respectively). We found 50 Yellow-breasted Chat nests in seed-tree stands, but only 2 were found in group-selection stands. We found 14 Prairie Warbler nests in seed-tree and none in group-selection stands. Mayfield nest success for Indigo Bunting was 30.9% in seed-tree stands and 41.9% in group-selection openings, but there was no difference in daily nest survival (0.952 ± 0.009 and 0.964 ± 0.010, respectively; $\chi^2 = 0.792$, $P = 0.37$). Our data suggest that Indigo Buntings can nest successfully in both regenerating seed-tree and group-selection stands; however, group-selection openings may be too small to support nesting Yellow-breasted Chats and Prairie Warblers. Public concerns about clear-cutting have resulted in increased use of uneven-aged management by the USDA Forest Service. However, before widespread implementation of group-selection cutting, additional research should be conducted to evaluate the effects of this management strategy on Neotropical migratory bird communities. *Received 18 November 2004, accepted 24 August 2005.*

Due to growing public concerns about clear-cutting and planting, the USDA Forest Service (USFS) is now relying more on natural regeneration systems involving both even-aged (e.g., seed-tree and shelterwood) and uneven-aged (e.g., single-tree and group-selection) silvicultural practices (Thill and Koerth 2005). On the Ouachita National Forest (ONF) in west-central Arkansas and east-central Oklahoma, clear-cutting has been largely replaced by seed-tree, shelterwood, single-tree, and group-selection management. Seed-tree management is similar to clear-cutting, but relies on natural regeneration from trees (typically 10–25 mature trees/ha) that are retained as a seed source (Holland et al. 1990). Under group-selection management, roughly 10% of the stand is clear-cut every 10

years within small (≤0.8 ha) patches that are allowed to regenerate naturally. If the surrounding stand (matrix) contains sufficient timber volume, it also may be thinned concurrently with the patch cuts (Smith 1986, Baker et al. 1996). Following a succession of treatments, this system creates a mosaic of forest patches of differing seral stages.

In general, tree removal results in the decline of many forest-interior bird species (Robinson et al. 1995, Thompson et al. 1995, Annand and Thompson 1997). Clear-cutting and heavy thinning treatments, however, can create habitat for a suite of early-successional bird species that would otherwise not occur, or occur infrequently, in forested landscapes (Annand and Thompson 1997, Germaine et al. 1997, Costello et al. 2000). Many of these early-successional species have experienced widespread population declines in recent years (Askins 1993, Litvaitis 1993). Group-selection silviculture may be appealing to wildlife managers because it creates habitat for early-successional species and allows some species that require mature forest to remain in the forest matrix after harvest (Chambers et al. 1999, Robinson and Robinson 1999, Costello et al. 2000). Furthermore, group-selection silvicul-

[1] Dept. of Biological Sciences, Arkansas State Univ., Jonesboro, AR 72467-0599, USA.

[2] USDA Forest Service, Southern Research Station, Wildlife Habitat and Silviculture Lab., 506 Hayter St., Nacogdoches, TX 75965-3556, USA.

[3] Current address: Ecosphere Environmental Services, 2257 Main Ave., Patio Level, Durango, CO 81301, USA.

[4] Corresponding author; e-mail: alterman@ecosphere-services.com

ture may increase overall bird abundance and diversity in some areas relative to untreated stands (Germaine et al. 1997). However, recent studies have shown that some early-successional species that occur in large forest openings do not use, or occur less frequently, in the smaller openings created by group-selection cuts (Annand and Thompson 1997, Rodewald and Smith 1998, Robinson and Robinson 1999, Costello et al. 2000). These data suggest that group-selection silviculture may not be suitable for some early-successional bird species in forested landscapes, and that a mix of silvicultural techniques may be necessary to maintain populations of these species (Annand and Thompson 1997, Chambers et al. 1999, Costello et al. 2000).

Whereas species presence/absence data are meaningful, they are not sufficient to uncover causes of reproductive failure that may limit populations associated with different silvicultural practices (Donovan et al. 1995). Several recent studies were designed to evaluate nest success in stands treated with group-selection harvests (e.g., King et al. 2001, Twedt et al. 2001, Gram et al. 2003, King and Degraaf 2004); however, only a few compared nest success of early-successional species in regenerating group-selection cuts to that in other treatments (King et al. 2001, Gram et al. 2003). Barber et al. (2001) compared nesting success on the ONF under several silvicultural treatments, including single-tree selection, but there are no data for evaluating nesting success under group-selection systems in this area. These data are needed, however, because the ONF plans substantial use of group-selection silviculture in the future.

Our objective was to compare occupancy and nesting success of three early-successional Neotropical migrants within stands treated with traditionally sized (≤0.8 ha) group-selection cuts and larger seed-tree cuts (10–16 ha) in the Ouachita Mountains of Arkansas. We chose the latter treatment because it is one of the primary even-aged regeneration systems being used on the ONF. We predicted that nest success would be lower in the small, group-selection cuts than in the larger seed-tree cuts. We also predicted higher rates of nest predation in group-selection than in seed-tree cuts. Parasitism by Brown-headed Cowbirds (*Molothrus ater*) is low on the ONF (Barber et al.

2001) and elsewhere in forested landscapes (Hoover and Brittingham 1993, Hoover et al. 1995, Hanski et al. 1996); therefore, we did not expect parasitism to be an important cause of nest failure. In addition to examining occupancy and nest success, we also evaluated microhabitat characteristics at nest sites. We compared habitat structure (1) between nests in small openings created by group-selection silviculture and those in larger openings created by seed-tree silviculture, and (2) between successful and unsuccessful nests.

METHODS

Study area.—Our study was conducted in 2000 and 2001 on the easternmost portion of the ONF in Garland, Perry, and Saline counties, Arkansas. Mixed pine-hardwood stands on the ONF occur at elevations ranging from approximately 90 to 820 m, and are characterized by a diverse mix of vegetation dominated by shortleaf pine (*Pinus echinata*), oaks (*Quercus* spp.), and hickories (*Carya* spp.). Common hardwoods include white oak (*Quercus alba*), black oak (*Q. velutina*), northern red oak (*Q. rubra*), post oak (*Q. stellata*), blackjack oak (*Q. marilandica*), mockernut hickory (*Carya tomentosa*), red maple (*Acer rubrum*), black tupelo (*Nyssa sylvatica*), winged elm (*Ulmus alata*), and flowering dogwood (*Cornus florida*). Common shrubs include winged sumac (*Rhus copallinum*), bigleaf snowbell (*Styrax grandifolia*), American beautyberry (*Callicarpa americana*), sparkleberry (*Vaccinium arboreum*), and other *Vaccinium* species.

Our study areas included three group-selection and three seed-tree stands; one of the latter had to be replaced in 2001 because it was inadvertently burned after the 2000 field season. Each treatment was 6 years post-harvest at the initiation of this study in 2000. Seed-tree stands ranged from 11 to 16 ha in size. Two of the group-selection stands were 12 ha, and each contained three openings. The third group-selection stand was 36 ha, and contained 15 openings. Our group-selection stands had been subjected only to their first treatment in a series of harvests; thus, these stands were in transition from an even-aged to an uneven-aged condition. The 21 group-selection openings from our three stands ranged in size from 0.14 to 0.76 ha (mean =

0.33 ha); however, 19 (91%) of the openings were <0.40 ha, which is half the upper limit (0.8 ha) used under traditional group-selection management. The mean nearest-neighbor distances between adjacent group-openings in the two smaller stands were 169 and 131 m, and the mean in the larger stand was 48 m. The ratios of early successional to forested habitat in the smaller group-selection stands were 1.0:13.8 and 1.0:7.5 ha, and the ratio in the larger stand was 1.0:9.0 ha.

Fieldwork.—Fieldwork was conducted between early May and mid-August in 2000 and 2001. We chose three focal study species—Indigo Bunting (*Passerina cyanea*), Yellow-breasted Chat (*Icteria virens*), and Prairie Warbler (*Dendroica discolor*)—for monitoring nest success in regenerating seed-tree and group-selection stands. These species were selected because they are common in forest openings in the ONF and their nests are relatively easy to find.

We located nests of target species by following adults carrying nest material or food, by observing them return to their nests to resume incubation, and by systematic searches of the study areas. We found a few additional Yellow-breasted Chat nests by attaching radio transmitters (Johnson et al. 1991) to the backs of females that we caught with mist nets. We tracked these birds until we found their nests or until the transmitters fell off. Nests were monitored an average of once every 3–4 days following the techniques of Martin and Geupel (1993). Whenever possible, we used binoculars to check nest status from a distance; however, we approached nests and checked contents when we expected a transition from one nesting phase to the next (e.g., incubation to nestling). When checking nest contents, we approached from one path and left from another to reduce the probability of attracting predators. Nests were considered successful if at least one host young fledged from the nest. Fledging was confirmed if we observed fledglings, heard begging calls outside of the nest, or observed adults carrying food or behaving defensively (chipping) on or near the expected fledging date. Nests were considered depredated if they were empty prior to the expected fledging date.

Habitat characteristics of nest sites were quantified within 5.0- and 11.3-m-radius cir-

cles (0.04 ha) centered on the nests, following a modified BBIRD Protocol (Martin et al. 1997). Between late June and August of each year, we measured habitat characteristics after nests had failed or the young had fledged. We did not conduct habitat sampling at nests that were abandoned prior to egg laying, deserted with eggs or chicks in the nest, or when nest fate was unknown.

Characteristics measured at nests included nest height, height and diameter of the nest plant, number and mean diameter of branches supporting the nest, and distance from the nest to the nearest forest edge. We also visually estimated nest concealment (from 1 m away) from the side of the nest in each of the four cardinal directions. At each location, we assigned a concealment index value from 1 to 6 (1 = 0–5, 2 = 6–25, 3 = 26–50, 4 = 51–75, 5 = 76–95, and 6 = 96–100%), corresponding to the percent of the nest that was concealed by vegetation. We then calculated the mean index value for concealment from the side.

Habitat characteristics measured within the 5.0-m-radius circles included slope, mean shrub height, shrub density in two size classes (≤2.5 and >2.5–8.0 cm diameter), and indices of various types of ground cover, including shrubs (in three height classes: 0–0.5, 0.5–1, and >1 m), grasses, forbs, ferns, vines, leaf litter, downed logs, and bare ground. Slope of the circle was measured using a clinometer. For all other measurements, we divided the circle into four quadrants, bounded by the four cardinal directions (Martin et al. 1997). Each characteristic was measured within each of the four quadrants, and a mean value was calculated. Mean shrub height was estimated visually using a meter stick as a reference. We considered all trees <3 m in height to be shrubs. We calculated shrub density by counting the number of stems in each size class within a 1-m² quadrat placed in each of the four quadrants of the circle. Indices of ground cover were estimated visually using the same categories as those used for nest concealment.

Characteristics measured in the 11.3-m-radius circles included mean tree height, percent canopy cover, and density of trees and snags. We used a clinometer to measure the height of all trees in the circle, and then calculated the mean height. Canopy cover was measured using a concave spherical densiometer. For

tree and snag density, we separated trees into three size classes (8–23, >23–38, and >38 cm dbh) and snags into two size classes (≤12 and >12 cm dbh). Density was calculated by counting the number of trees and snags in each size class.

Statistical analyses.—We calculated daily nest survival probabilities for Indigo Bunting and Yellow-breasted Chat using the Mayfield (1975) method with the standard error estimator developed by Johnson (1979). We did not use the Mayfield method for Prairie Warbler because we found too few (<20) nests (Hensler and Nichols 1981); instead, we calculated apparent nest success (the number of successful nests divided by the total number of nests). For Indigo Bunting and Yellow-breasted Chat, we calculated daily survival probabilities for each phase of nesting (egg laying, incubation, and nestling), as well as for the entire nesting period. We only included nests in the Mayfield analysis that were observed for >1 day (i.e., we did not include nests that were found on the day of failure or fledging). Survival estimates were based on a 25-day nesting period for Indigo Bunting (4 egg-laying days, 12 incubation days, and 9 nestling days) and a 24-day nesting period for Yellow-breasted Chat (4 egg-laying days, 12 incubation days, and 8 nestling days) based on our nest-monitoring data. To calculate nest success, survival probabilities were raised to the power of the number of days in the nesting period (e.g., daily nest survival^{25} = nest success for Indigo Bunting). We tested for a year effect between 2000 and 2001 by comparing daily nest survival of Indigo Bunting and Yellow-breasted Chat using program CONTRAST (Hines and Sauer 1989) and an alpha level of 0.05. There were no significant differences between years for either species; therefore, we used CONTRAST (Hines and Sauer 1989) to compare daily nest survival of Indigo Bunting in seed-tree versus group-selection stands. We did not compare daily survival between the two stand types for Yellow-breasted Chat because we found too few nests in group-selection stands. We could not compare apparent nest success of Prairie Warbler in the two stand types because this species did not nest in group-selection stands.

We used Minitab (Minitab, Inc. 1998) to conduct all statistical analyses for habitat var-

iables. We examined plots of the data and tested for normality. Most habitat variables were normally distributed; therefore, we tested for a year effect using two-sample *t*-tests (alpha level = 0.05). Nest-site habitat characteristics were similar between years for all species and data were pooled across years. We used two-sample *t*-tests to compare nest-site habitat variables between group-selection and seed-tree stands for Indigo Bunting. To determine whether habitat variables differed between the two stand types, we also evaluated effect size and 95% CI around the effect size (Anderson et al. 2001, Di Stefano 2004) instead of using only the *P*-values generated from *t*-tests.

To determine which habitat variables best explained nest success, we conducted binary logistic regression analysis. Logistic regression was conducted for Indigo Bunting nests in group-selection and seed-tree stands as well as for all nests pooled, and for Yellow-breasted Chat nests in seed-tree stands. Successful and unsuccessful nests were binary independent variables. For each analysis, we reduced the number of candidate independent variables by conducting univariate logistic regression analyses for each habitat variable (Hosmer and Lemeshow 1989)—retaining variables that differed between successful and failed nests and using an alpha level of ≤0.15. We tested for correlation between the retained variables by calculating Pearson correlation coefficients; when two or more variables were correlated (*P* < 0.05), we included the variable that we thought was more biologically meaningful, based on our knowledge of the birds' behavior and ecology. For each analysis, we then performed logistic regression using all variables (full model) and on all subsets of the full model. We ranked models using Akaike's Information Criterion modified for small sample size (AIC$_c$; Anderson et al. 2001), and present all models where $\Delta AIC_c <$ 2. If ΔAIC_c for all other candidate models was > 2, we present the second-best model as a comparison. Model fit was evaluated using the Hosmer-Lemeshow lack-of-fit test (Hosmer and Lemeshow 1989), in which higher *P*-values indicate that the data fit the model well.

RESULTS

Nest success.—We found a total of 82 Indigo Bunting (54 in seed-tree and 28 in group-

TABLE 1. Daily survival for Indigo Bunting nests in seed-tree (n = 48) and group-selection stands (n = 25) on the Ouachita National Forest, Arkansas, 2000–2001.

	Seed-tree			Group-selection				
Nest phase	Failed nests	Exposure days	Daily survival ± SE	Failed nests	Exposure days	Daily survival ± SE	χ^2	P[a]
Egg laying	1	21	0.952 ± 0.047	1	26	0.962 ± 0.038	0.231	0.88
Incubation	8	283	0.972 ± 0.010	6	195	0.969 ± 0.012	0.248	0.88
Nestling	17	242	0.930 ± 0.017	5	117	0.957 ± 0.019	1.209	0.27
Total	26	545	0.952 ± 0.009	12	338	0.964 ± 0.010	0.792	0.37

[a] χ^2 and P-values were calculated using program CONTRAST (Hines and Sauer 1989).

selection stands), 52 Yellow-breasted Chat (50 in seed-tree and 2 in group-selection stands), and 14 Prairie Warbler (all in seed-tree stands) nests. The two chat nests in group-selection stands were found during different years, but both were located in the same stand and within the largest of all 21 group-openings (0.76 ha). We observed male Prairie Warblers in 3 of the 21 group-selection openings, but we did not observe any females or nesting activity at these sites. As these two latter species were rarely found in group-selection stands, we could not compare nesting success between the two treatment types.

Mayfield nest success for Yellow-breasted Chats in seed-tree stands was 31.3% (n = 46 nests, excluding 4 discovered on the day of fledging or failure) and overall daily nest survival was 0.951 ± 0.009 SE. Both chat nests found in group-selection stands failed. Apparent nest success for Prairie Warblers was 45.4% (n = 11). Three Prairie Warbler nests were not included because we could not determine nest fate.

Mayfield nest success for Indigo Buntings was 41.0% in group-selection (n = 25) and 29.2% in seed-tree stands (n = 48), but there was no significant difference in daily nest survival between the two stand types (Table 1). Nine of the 82 nests were not included in the analysis because they were discovered either on the day of fledging or failure.

Predation was the primary cause of nest failure for Indigo Bunting (37 of 44 failed nests; 84.1%), Yellow-breasted Chat (30 of 33 failed nests; 90.9%), and Prairie Warbler (5 of 6 failed nests; 83.3%). For all species combined, 72 of 83 (86.7%) nests failed because of predation. Nest desertion (eggs or chicks present) was the second highest cause of nest failure for buntings (6 of 44 failed nests;

13.6%), chats (2 of 33 failed nests; 6.1%), and warblers (1 of 6 failed nests; 16.7%). Other causes of nest failure included nest abandonment prior to egg laying (1 of 33 failed nests; 3.0% for chats) and brood parasitism by Brown-headed Cowbird (1 of 44 failed nests; 2.3% for buntings). Overall nest predation for Indigo Bunting was 45.1% (37 of 82 nests). Cowbird eggs were observed in three bunting nests, but only one of these nests failed to fledge host young. The other two nests fledged at least one cowbird and one bunting. Overall nest predation for Yellow-breasted Chat was 57.7% (30 of 52 nests). Cowbird eggs were also observed in two chat nests (3.8%), but these nests failed due to predation. Overall nest predation for Prairie Warbler was 35.7% (5 of 14 nests). Cowbird parasitism was not observed in Prairie Warbler nests.

Habitat characteristics.—Eleven habitat variables differed between Indigo Bunting nests in seed-tree compared with group-selection stands (Table 2). Distance to forest edge, tree height, and grass and forb cover were greater at nests in seed-tree stands. Fern and vine cover, total tree density, density of trees 8–23 and >38 cm dbh, total snag density, and density of snags >12 cm dbh all were greater at nests in group-selection stands.

Based on the results of the univariate regressions and Pearson correlation tests, we identified four habitat variables for multiple logistic regression analysis that explained the variation in Indigo Bunting nest success in group-selection stands: diameter of branches supporting the nest, distance to forest edge, mean shrub height, and vine cover. The best models (ΔAIC_c < 2) explaining nest success in group-selection stands indicated that nests in areas with increased cover of vines were more likely to be successful (Table 3). The

TABLE 2. Habitat characteristics at Indigo Bunting nests in group-selection ($n = 26$)[a] and seed-tree ($n = 42$)[a] stands on the Ouachita National Forest, Arkansas, 2000–2001.

Habitat characteristic[b]	Group-selection mean ± SE	Seed-tree mean ± SE	Effect size	95% CI	P[c]
Distance to forest edge (m)	15.80 ± 2.30	35.71 ± 6.88	−19.91	−5.27 to −34.56	0.009
Grass cover index[d]	1.86 ± 0.14	2.63 ± 0.15	−0.78	−0.36 to −1.19	<0.001
Forb cover index[d]	1.13 ± 0.03	1.55 ± 0.06	−0.42	−0.27 to −0.57	<0.001
Fern cover index[d]	1.42 ± 0.10	1.02 ± 0.01	0.40	0.20 to 0.60	<0.001
Vine cover index[d]	2.13 ± 0.16	1.71 ± 0.10	0.42	0.04 to 0.80	0.030
Tree height (m)	13.03 ± 0.68	17.55 ± 0.93	−4.52	−2.23 to −6.83	<0.001
Total tree density[e]	11.63 ± 1.80	6.12 ± 0.64	5.51	1.61 to 9.40	0.007
Tree density (8–23 cm dbh)[e]	8.48 ± 1.60	2.98 ± 0.54	5.51	1.98 to 9.03	0.003
Tree density (>38 cm dbh)[e]	0.93 ± 0.20	0.45 ± 0.12	0.47	0.00 to 0.95	0.049
Total snag density[e]	3.30 ± 0.49	1.00 ± 0.24	2.30	1.19 to 3.41	<0.001
Snag density (>12 cm dbh)[e]	2.37 ± 0.38	0.55 ± 0.17	1.82	0.98 to 2.66	<0.001

[a] Habitat characteristics were not measured at nests that were abandoned prior to egg laying, deserted with eggs or chicks in the nest, or when nest fate was unknown.
[b] See Alterman (2002) for nonsignificant habitat data.
[c] P-values from two-sample t-tests.
[d] Index based on cover classes described in methods.
[e] Tree and snag densities are reported per 0.04 ha.

best model also indicated that nests in areas with shorter shrubs were more likely to be successful. Four habitat variables were considered for multiple logistic regression models explaining variation in bunting nest success in seed-tree stands: nest height, nest concealment from the side, shrub cover 0.5–1.0 m, and mean tree height. The models that best explained variation in nests success in seed-tree stands ($\Delta AIC_c < 2$) indicated that nests lower to the ground in areas with shorter trees were more likely to be successful (Table 3). The best model also indicated that nests in areas with increased cover of shrubs 0.5–1.0 m tall were more likely to be successful; however, the Hosmer-Lemeshow lack-of-fit test indicated that the data were not a good fit to the model (Table 3). Four habitat variables were also considered for multiple logistic regression models explaining variation in nest success for pooled Indigo Bunting nests: mean shrub height, vine cover, mean tree height, and density of trees >38 cm dbh. The model that best explained variation in nest success for the pooled sample indicated that nests in areas with shorter shrubs, shorter trees, and fewer large trees were more likely to be successful (Table 3). Increased vine cover was also an indicator of nest success in the second-best model.

Based on the results of the univariate regressions and Pearson correlation tests, we identified five habitat variables for inclusion in multiple logistic regression analysis explaining variation in Yellow-breasted Chat nest success in seed-tree stands: nest height, nest concealment from the side, distance to forest edge, density of trees >38 cm dbh, and density of snags <12 cm dbh. Most of the models that best explained variation in nest success indicated that nests lower to the ground and farther from the forest edge were more likely to be successful (Table 3). Some of the models also indicated that nests in areas with fewer large trees and small snags were more likely to be successful.

DISCUSSION

Occupancy and nest success.—Our data clearly show that Indigo Buntings can nest successfully in regenerating forest created by group-selection and seed-tree silviculture. Furthermore, daily nest survival was similar among treatments and we did not observe elevated levels of predation in group-selection openings. As expected, parasitism by Brown-headed Cowbird was very low for all species. Few studies have presented similar comparative data on nest success of early-successional species in large and small forest openings. Our results are consistent with those of King et al. (2001), who found no difference in daily nest survival for Chestnut-sided Warbler (*Dendroica pensylvanica*) in 6- to 10-ha clearcuts (0.993) and 0.2- to 0.7-ha group-selection cuts (0.987) in New Hampshire. They also

TABLE 3. Logistic regression models explaining nest success for Indigo Buntings and Yellow-breasted Chats on the Ouachita National Forest, Arkansas 2000–2001.

Species/Treatment	Model	AIC_c	ΔAIC_c	$-2\log_e(L)$	w[a]	P[b]	Fit[c]
Indigo Bunting							
Group-selection stands	-3.148 + (-1.807 shrub height) + (2.922 vine cover)	23.62	0.00	16.36	0.355	<0.001	0.269
	-1.466 + (-7.127 branch diameter) + (2.393 vine cover)	24.98	1.36	17.72	0.180	0.001	0.805
Seed-tree stands	1.649 + (-2.773 nest height) + (2.294 shrub cover 0.5–1.0 m) + (-0.159 tree height)	48.96	0.00	38.74	0.264	0.006	0.016
	4.941 + (-2.261 nest height) + (-0.138 tree height)	49.57	0.61	42.31	0.195	0.011	0.174
Pooled	2.755 + (-1.338 shrub height) + (1.125 vine cover) + (-0.132 tree height) + (-0.737 tree density >38 cm dbh)	84.55	0.00	71.02	0.530	<0.001	0.209
	0.747 + (-1.142 shrub height) + (0.906 vine cover) + (-0.754 tree density >38 cm dbh)	87.51	2.95	77.29	0.120	0.001	0.356
Yellow-breasted Chat							
Seed-tree stands	2.028 + (-2.549 nest height) + (0.022 distance to edge) + (-0.647 tree density >38 cm dbh)	49.33	0.00	40.04	0.10	0.021	0.351
	1.100 + (-2.327 nest height) + (0.021 distance to edge)	49.57	0.24	42.82	0.09	0.031	0.689
	1.602 + (-2.413 nest height) + (0.018 distance to edge) + (-1.179 snag density <12 cm dbh)	50.00	0.67	40.71	0.07	0.028	0.863
	2.615 + (-2.752 nest height) + (0.020 distance to edge) + (-0.660 tree density >38 cm dbh) + (-1.273 snag density <12 cm dbh)	50.09	0.76	38.09	0.07	0.020	0.055
	2.275 + (-2.121 nest height) + (-1.300 snag density <12 cm dbh)	50.23	0.90	43.48	0.06	0.042	0.394
	3.270 + (-2.400 nest height) + (-0.613 tree density >38 cm dbh) + (-1.431 snag density <12 cm dbh)	50.44	1.11	41.15	0.06	0.034	0.087
	-0.467 + (0.022 distance to edge) + (-0.601 tree density >38 cm dbh)	50.55	1.22	43.80	0.05	0.050	0.551
	-1.079 + (0.020 distance to edge)	50.72	1.39	46.35	0.05	0.064	0.157
	-2.773 + (-2.208 nest height) + (-0.607 tree density >38 cm dbh)	50.73	1.40	43.98	0.05	0.055	0.612
	-0.704 + (0.017 distance to edge) + (-0.992 snag density <12 cm dbh)	51.04	1.71	44.29	0.04	0.064	0.106

[a] Akaike weight.
[b] Probability values from χ^2 test indicating overall model significance.
[c] Probability from Hosmer-Lemeshow lack-of-fit test (Hosmer and Lemeshow 1989).

found no difference in daily nest survival after pooling data for 16 species. Gram et al. (2003) also reported no difference in daily nest survival for Indigo Buntings in regenerating 3- to 13-ha clear-cuts (0.969) and stands treated with both group- and single-tree harvest (0.967) in the Missouri Ozarks.

From our study, it is evident that group-selection openings <0.4 ha may be too small to support nesting Yellow-breasted Chats or Prairie Warblers. This conclusion is consistent with Annand and Thompson's (1997) presence/absence data for these species in clear-cuts and group-selection openings. In our study, chats did nest in one group-selection opening; however, this was the largest (0.76 ha) of the 21 openings. Chats were not observed in any of the other 20 group-openings (all but 1 were <0.4 ha). Prairie Warblers were also observed in two of the group-selection cuts, one of which was the largest opening, while the other was <0.4 ha. Because we monitored nests frequently, we are confident that we spent enough time in the group-selection stands to determine that both Yellow-breasted Chats and Prairie Warblers were indeed absent from the majority of the group-selection openings. In the near future, forest managers in the ONF are considering implementing experimental clear-cuts of intermediate size (2 ha), which may be more suitable for nesting Yellow-breasted Chats and Prairie Warblers. Additional research is needed to evaluate the minimum patch-size requirements for these and other early-successional species.

The change in condition of group-selection stands over time may also be an important factor for early-successional birds. The group-selection stands in this study had been treated only once, and represented a transition phase from an even-aged to an uneven-aged condition. The effects of repeated treatments every 10–15 years are unknown and should be studied. Nevertheless, occupancy and nest-success data are important for early-successional species in transitional group-selection stands because all even-aged stands go through this process when subjected to uneven-aged management.

Habitat characteristics.—Although there were a number of significant differences in microhabitat variables at Indigo Bunting nests

in seed-tree versus group-selection openings (Table 2), daily nest survival in the two stand types was similar. Some of these differences are more likely a function of the differences in opening size rather than avian selection for specific nest-site characteristics. The results of regression analyses indicated that most microhabitat variables were similar for successful and failed nests of Indigo Buntings and Yellow-breasted Chats; however, differences in a few key variables may be biologically important to nesting success. Increased vegetative cover surrounding nests explained a large portion of the variation in nest success in group-selection (vine cover) and seed-tree (shrub cover 0.5–1.0 m tall) stands, and for all nests pooled (vine cover). Nests in areas with more vegetative cover may be less conspicuous to some predators. In addition to shrubs, our study areas contained several vine species, especially muscadine grape (*Vitis rotundifolia*), which often afforded excellent vegetative cover.

Logistic regression models also indicated a negative relationship between nest height and probability of nest success for buntings and chats in seed-tree stands. Nests placed lower to the ground may be less conspicuous to some avian predators, which usually detect nests from above. In contrast, Ricketts and Ritchison (2000) found that height of Yellow-breasted Chat nests was greater for successful (median = 0.83 m) than failed (median = 0.75 m) nests in mixed woodland and early-successional habitat in Kentucky. Burhans et al. (2002) also found increased nest predation at Indigo Bunting nests that were lower to the ground. There may be an optimal range of nest height that reduces predation rates in specific habitats, and this may differ among habitat types and geographical locations.

One other habitat variable that may be biologically important to some early-successional species in the ONF is distance to the forest edge. In our study, increased distance to the forest edge was important in explaining nest success for Yellow-breasted Chat in seed-tree stands. Because predation was the primary cause of nest failure for chats, our model suggests that predation may have increased with decreasing distance to the habitat edge. Distance to edge did not explain variation in Indigo Bunting nest success, however. Wood-

ward et al. (2001) also found some evidence of edge effect on Yellow-breasted Chat (but not Indigo Bunting) nest success in the Missouri Ozarks. In that study, chat nests closest to edges (≤20 m) had higher predation rates than nests 21–40 m from forest edges. Predation increased, however, at nests >40 m from edges. Other recent studies suggest little or no edge effect associated with openings created by silviculture in predominantly forested landscapes for forest-interior (Hanski et al. 1996, Duguay et al. 2001, Rodewald 2002) and early-successional species (Hanski et al. 1996, King et al. 2001). However, Manolis et al. (2000) showed that many studies that failed to detect edge effects in forested landscapes did not have sufficient power. Other recent studies in forested landscapes have documented mixed results—that is, they showed edge-related increases in nest predation for some species but not others (Burke and Nol 2000, Flaspohler et al. 2001).

Management implications.—Our results suggest that group-selection silviculture may not be the most appropriate strategy on the ONF for providing habitat for some early-successional, migratory bird species. If seed-tree cuts are replaced by group-selection cuts on a large scale, this management strategy might reduce availability of nesting habitat for some early-successional species, such as Yellow-breasted Chat and Prairie Warbler. Suitable habitat for these species during the breeding season is important because many have exhibited population declines in Arkansas and elsewhere in recent decades (James et al. 1992, Sauer et al. 2001).

The USFS and other land management agencies have begun to shift their silvicultural practices toward uneven-aged management (Costello et al. 2000). Group-selection silviculture may increase avian abundance and diversity in forested communities because these treatments create habitat for early-successional species while retaining forested habitat and many forest-interior species (Germaine et al. 1997). However, several studies have shown that early-successional species occur less frequently in small forest openings (Annand and Thompson 1997, Rodewald and Smith 1998, Robinson and Robinson 1999). Our data are consistent with these latter findings. Implementation of widespread management techniques in national forests that improve habitat for some species at the expense of other species of conservation concern, such as Yellow-breasted Chat and Prairie Warbler, should be undertaken with the knowledge of the potential negative impacts on those species. Before its widespread adoption, forest managers should understand how group-selection management techniques affect the abundance and diversity of the entire avian community. Implementing a mix of silvicultural techniques may be necessary to maintain populations of early-successional species in the ONF and similar forested landscapes.

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LITERATURE CITED

ALTERMAN, L. E. 2002. Nesting success and postfledging survival of Neotropical migratory birds in the Ouachita Mountains of Arkansas. M.Sc. thesis, Arkansas State University, State University.

ANDERSON, D. R., W. A. LINK, D. K. JOHNSON, AND K. P. BURNHAM. 2001. Suggestions for presenting the results of data analysis. Journal of Wildlife Management 65:373–378.

ANNAND, E. M. AND F. R. THOMPSON, III. 1997. Forest bird response to regeneration practices in central hardwood forests. Journal of Wildlife Management 61:159–171.

ASKINS, R. A. 1993. Population trends in grassland, shrubland, and forest birds in eastern North America. Current Ornithology 11:1–34.

BAKER, J. B., M. D. CAIN, J. M. GULDIN, P. A. MURPHY, AND M. G. SHELTON. 1996. Uneven-aged silviculture for the loblolly and shortleaf pine forest cover types. General Technical Report SO-118, USDA Forest Service, Southern Research Station, Asheville, North Carolina.

BARBER, D. R., T. E. MARTIN, M. A. MELCHIORS, R. E. THILL, AND T. B. WIGLEY. 2001. Nesting success of birds in different silvicultural treatments in southeastern U.S. pine forests. Conservation Biology 15:196–207.

BURHANS, D. E., D. DEARBORN, F. R. THOMPSON, III, AND J. FAABORG. 2002. Factors affecting predation at songbird nests in old fields. Journal of Wildlife Management 66:240–249.

BURKE, D. M. AND E. NOL. 2000. Landscape and fragment size effects on reproductive success of for-

est-breeding birds in Ontario. Ecological Applications 10:1749–1761.

CHAMBERS, C. L., W. C. MCCOMB, AND J. C. TAPPEINER, II. 1999. Breeding bird responses to three silvicultural treatments in the Oregon Coast Range. Ecological Applications 9:171–185.

COSTELLO, C. A., M. YAMASAKI, P. J. PEKINS, W. B. LEAK, AND C. D. NEEFUS. 2000. Songbird response to group selection harvests and clearcuts in a New Hampshire hardwood forest. Forest Ecology and Management 127:41–54.

DI STEFANO, J. 2004. A confidence interval approach to data analysis. Forest Ecology and Management 187:173–183.

DONOVAN, T. M., F. R. THOMPSON, III, J. FAABORG, AND J. R. PROBST. 1995. Reproductive success of migratory birds in habitat sources and sinks. Conservation Biology 9:1380–1395.

DUGUAY, J. P., P. BOHALL WOOD, AND J. V. NICHOLS. 2001. Songbird abundance and avian nest survival rates in forests fragmented by different silvicultural treatments. Conservation Biology 15:1405–1415.

FLASPOHLER, D. J., S. A. TEMPLE, AND R. N. ROSENFIELD. 2001. Species-specific edge effects on nest success and breeding bird density in a forested landscape. Ecological Applications 11:32–46.

GERMAINE, S. S., S. H. VESSEY, AND D. E. CAPEN. 1997. Effects of small forest openings on the breeding bird community in a Vermont hardwood forest. Condor 99:708–718.

GRAM, W. K., P. A. PORNELUZI, R. L. CLAWSON, J. FAABORG, AND S. C. RICHTER. 2003. Effects of experimental forest management on density and nesting success of bird species in Missouri Ozark forests. Conservation Biology 17:1324–1337.

HANSKI, I. K., T. J. FENSKE, AND G. J. NIEMI. 1996. Lack of edge effect in nesting success of breeding birds in managed forest landscapes. Auk 113:578–585.

HENSLER, G. L. AND J. D. NICHOLS. 1981. The Mayfield method of estimating nesting success: a model, estimators and simulation results. Wilson Bulletin 93:42–53.

HINES, J. E. AND J. R. SAUER. 1989. Program CONTRAST: a general program for the analysis of several survival or recovery rate estimates. Wildlife Technical Report 24, U.S. Fish and Wildlife Service, Washington, D.C.

HOLLAND, I., G. ROFE, AND D. ANDERSON. 1990. Forests and forestry. Interstate, Danville, Illinois.

HOOVER, J. P. AND M. C. BRITTINGHAM. 1993. Regional variation in brood parasitism of Wood Thrushes. Wilson Bulletin 105:228–238.

HOOVER, J. P., M. C. BRITTINGHAM, AND L. J. GOODRICH. 1995. Effects of forest patch size on nesting success of Wood Thrushes. Auk 112:146–155.

HOSMER, D. W. AND S. LEMESHOW. 1989. Applied logistic regression. John Wiley and Sons, New York.

JAMES, F. C., D. A. WIEDENFELD, AND S. E. MCCULLOCH. 1992. Trends in breeding populations of warblers: declines in the southern highlands and increases in the lowlands. Pages 43–56 *in* Ecology and conservation of Neotropical migrant landbirds (J. M. Hagan and D. W. Johnston, Eds.). Smithsonian Institution Press, Washington, D.C.

JOHNSON, D. H. 1979. Estimating nest success: the Mayfield method and an alternative. Auk 96:651–661.

JOHNSON, G. D., J. L. PEBWORTH, AND H. O. KRUEGER. 1991. Retention of transmitters attached to passerines using a glue-on technique. Journal of Field Ornithology 62:486–491.

KING, D. I. AND R. M. DEGRAAF. 2004. Effects of group-selection opening size on the distribution and reproductive success of an early-successional shrubland bird. Forest Ecology and Management 190:179–185.

KING, D. I., R. M. DEGRAF, AND C. R. GRIFFIN. 2001. Productivity of early successional shrubland birds in clearcuts and groupcuts in an eastern deciduous forest. Journal of Wildlife Management 65:345–350.

LITVAITIS, J. A. 1993. Response of early-successional vertebrates to historic changes in land use. Conservation Biology 7:866–873.

MANOLIS, J. C., D. E. ANDERSON, AND F. J. CUTHBERT. 2000. Patterns in clearcut edge and fragmentation effect studies in northern hardwood-conifer landscapes: retrospective power analysis and Minnesota results. Wildlife Society Bulletin 28:1088–1101.

MARTIN, T. E. AND G. R. GEUPEL. 1993. Nest-monitoring plots: methods for locating nests and monitoring success. Journal of Field Ornithology 64:507–519.

MARTIN, T. E., C. R. PAYNE, C. J. CONWAY, W. M. HOCHACHKA, P. ALLEN, AND W. JENKINS. 1997. BBIRD field protocol. Cooperative Wildlife Research Unit, University of Montana, Missoula.

MAYFIELD, H. F. 1975. Suggestions for calculating nest success. Wilson Bulletin 87:456–466.

MINITAB, INC. 1998. Minitab user's guide: release 12 for Windows. Minitab, Inc., State College, Pennsylvania.

RICKETTS, M. S. AND G. RITCHISON. 2000. Nesting success of Yellow-breasted Chats: effects of nest site and territory vegetation structure. Wilson Bulletin 112:510–516.

ROBINSON, S. K., F. R. THOMPSON, III, T. M. DONOVAN, D. R. WHITEHEAD, AND J. FAABORG. 1995. Regional forest fragmentation and the nesting success of migratory birds. Science 267:1987–1990.

ROBINSON, W. D. AND S. K. ROBINSON. 1999. Effects of selective logging on forest bird populations in a fragmented landscape. Conservation Biology 13:58–66.

RODEWALD, A. D. 2002. Nest predation in forested regions: landscape and edge effects. Journal of Wildlife Management 66:634–640.

RODEWALD, P. G. AND K. G. SMITH. 1998. Short-term effects of understory and overstory management

on breeding birds in Arkansas oak-hickory forests. Journal of Wildlife Management 62:1411–1417.

SAUER, J. R., J. E. HINES, AND J. FALLON. 2001. The North American Breeding Bird Survey: results and analysis 1966–2000, ver. 2001.2. USGS Patuxent Wildlife Research Center, Laurel, Maryland. http://www.mbr-pwrc.usgs.gov/bbs/bbs.html (accessed 15 October 2002).

SMITH, D. M. 1986. The practice of silviculture. John Wiley and Sons, New York.

THILL, R. E. AND N. E. KOERTH. 2005. Breeding birds of even- and uneven-aged pine forests of eastern Texas. Southeastern Naturalist 41:153–176.

THOMPSON, F. R., III, J. R. PROBST, AND M. G. RAPHAEL. 1995. Impacts of silviculture: overview and management recommendations. Pages 201–219 *in* Ecology and management of Neotropical migratory birds (T. E. Martin and D. M. Finch, Eds.). Oxford University Press, New York.

TWEDT, D. J., R. R. WILSON, J. L. HENNE-KERR, AND R. B. HAMILTON. 2001. Nest survival of forest birds in the Mississippi Alluvial Valley. Journal of Wildlife Management 65:450–460.

WOODWARD, A. A., A. D. FINK, AND F. R. THOMPSON, III. 2001. Edge effects and ecological traps: effects on shrubland birds in Missouri. Journal of Wildlife Management 65:668–675.